2009-03

Geothermal HVAC systems -- a business case analysis for Net Zero Plus

Trahan, Ronnie Dale

Monterey, California: Naval Postgraduate School

http://hdl.handle.net/10945/4827

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

GEOTHERMAL HVAC SYSTEMS – A BUSINESS CASE ANALYSIS FOR NET ZERO PLUS

by

Ronnie D. Trahan, Jr.

March 2009

Thesis Advisor: Dan Nussbaum
Second Reader: Barbara Brygider

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE | *Form Approved OMB No. 0704-0188*

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE March 2009

3. REPORT TYPE AND DATES COVERED Master's Thesis

4. TITLE AND SUBTITLE Geothermal HVAC Systems – A Business Case Analysis for Net Zero Plus

5. FUNDING NUMBERS

6. AUTHOR(S) Ronnie D. Trahan, Jr.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (maximum 200 words)

Net Zero Plus (NZ+) is an approved Fiscal Year 2008 Joint Capability Technology Demonstration (JCTD) initiative led by the United States Army Rapid Equipping Force (REF) and the Office of the Secretary of Defense (OSD), Defense Research and Engineering (DDR&E). The purpose of the JCTD initiative is to identify significant military needs and match them to mature technologies or technology demonstration programs, so that military needs can be more rapidly addressed.

The effective implementation of the NZ+ JCTD initiative directly supports the Power Surety Task Force (PSTF) whose mission is to "coordinate Department of the Defense efforts to operationalize efficient devices, conservation practices, intelligent power management, and alternative and renewable power generation, in order to reduce the operational, economic and environmental vulnerabilities associated with the use and transportation of fossil fuels". To achieve effectively and efficiently its overall goals, NZ+ JCTD looks into three main categories: energy supply, energy demand, and smart energy distribution.

The purpose of this study is to support one of the many Net Zero Plus project initiatives. Specifically, this thesis will assist in determining whether or not it is economically advantageous to install a geothermal HVAC system in a highly-insulated monolithic dome.

14. SUBJECT TERMS Net Zero Plus, Power Surety Task Force, Monolithic Dome, Business Case Analysis. Joint Capability Technology Demonstration, Rapid Equipping Force

15. NUMBER OF PAGES 57

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

GEOTHERMAL HVAC SYSTEMS – A BUSINESS CASE ANALYSIS FOR NET ZERO PLUS

Ronnie Dale Trahan, Jr.
Lieutenant Commander, Supply Corps, U.S. Navy
B.S., University of Southwestern Louisiana, 1997

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
March 2009

Author: Ronnie D. Trahan, Jr.

Approved by: Dr. Dan Nussbaum
Thesis Advisor

Ms. Barbara Brygider
Second Reader

Dr. Robert F. Dell
Chairman, Department of Operations Research

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

Net Zero Plus (NZ+) is an approved Fiscal Year 2008 Joint Capability Technology Demonstration (JCTD) initiative led by the United States Army Rapid Equipping Force and the Office of the Secretary of Defense, Defense Research and Engineering. The purpose of the JCTD initiative is to identify significant military needs and match them to mature technologies or technology demonstration programs, so that military needs can be more rapidly addressed.

The effective implementation of the NZ+ JCTD initiative directly supports the Power Surety Task Force whose mission is to "coordinate Department of the Defense efforts to operationalize efficient devices, conservation practices, intelligent power management, and alternative and renewable power generation, in order to reduce the operational, economic and environmental vulnerabilities associated with the use and transportation of fossil fuels". To achieve effectively and efficiently its overall goals, NZ+ JCTD looks into three main categories: energy supply, energy demand, and smart energy distribution.

The purpose of this study is to support one of the many NZ+ project initiatives. Specifically, this thesis assists in determining whether or not it is economically advantageous to install a geothermal heating, ventilating and air conditioning (HVAC) system in a highly-insulated monolithic dome.

We find for a 30-year cost life cycle the geothermal HVAC system needs to save 37.9% of the fuel normally consumed by the traditional HVAC system to be financially attractive.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

Net Zero Plus (NZ+) is an approved Fiscal Year 2008 Joint Capability Technology Demonstration (JCTD) initiative led by the United States Army Rapid Equipping Force (REF) and the Office of the Secretary of Defense, Defense Research and Engineering. The purpose of the JCTD initiative is to identify significant military needs and match them to mature technologies or technology demonstration programs, so that military needs can be more rapidly addressed.

The effective implementation of the NZ+ JCTD initiative directly supports the REF and Power Surety Task Force, whose mission is to "coordinate Department of the Defense efforts to operationalize efficient devices, conservation practices, intelligent power management, and alternative and renewable power generation, in order to reduce the operational, economic and environmental vulnerabilities associated with the use and transportation of fossil fuels". To achieve its overall goals, NZ+ JCTD looks into three main categories: energy supply, energy demand, and smart energy distribution.

The purpose of this study is to support one of the many NZ+ project initiatives. Specifically, this thesis assists in determining whether or not it is economically advantageous to install a geothermal HVAC system in a highly-insulated monolithic dome.

This business case analysis was performed on the 3-ton geothermal HVAC system installed in the extremely well-insulated monolithic dome at Contingency Operating Base King located at the National Training Center on Fort Irwin, CA to evaluate its net present value over a 10- year, 20-year, and 30-year cost life cycle at a discount rate of 10%. The results of the baseline analysis are summarized in the following table.

LIFE CYCLE	**LAMBDA**
10-YEAR	54.9%
20-YEAR	41.3%
30-YEAR	37.9%

For clarity we have developed the metric, *lambda*. The measure in percent savings of fuel normally used by a generator to supply power to a geothermal HVAC system rather than a traditional HVAC system represents the value of *lambda.* Simply stated, *lambda* indicates whether the geothermal HVAC system is a financially attractive investment. For example, if the geothermal HVAC system saves only a small fraction of the generator fuel, such as 10%, then we would expect that the geothermal HVAC system is not financially attractive. However, at 90% fuel savings, we would expect that the geothermal HVAC system is very attractive. Referring to the table above, we see that for a 30-year cost life cycle the geothermal HVAC system needs to save 37.9% of the fuel normally consumed by the traditional HVAC system to be financially attractive.

ACKNOWLEDGMENTS

First and far most, I thank God for without Him nothing would be possible. I would also like to thank Dr. Dan Nussbaum who with patience and understanding guided me through this entire process.

Additionally, I would like to thank Ms. Barbara Brygider and her team for supplying me with the data required for the successful completion of my thesis.

Last but certainly not least, I would like to thank my entire family, immediate and extended, for their steadfast support. Without their constant encouragement, the completion of this thesis would not have been possible.

I sincerely thank all of you!

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

A. NET ZERO PLUS' JUSTIFICATION

Net Zero Plus (NZ+) is an approved Fiscal Year 2008 Joint Capability Technology Demonstration (JCTD) initiative led by the United States Army Rapid Equipping Force and the Office of the Secretary of Defense, Defense Research and Engineering. The purpose of the JCTD initiative is to identify significant military needs and match them to mature technologies or technology demonstration programs, so that military needs can be more rapidly addressed (Ong, December 2007).

The effective implementation of the NZ+ JCTD initiative directly supports the Power Surety Task Force (PSTF) whose mission is to "coordinate Department of the Defense (DoD) efforts to operationalize efficient devices, conservation practices, intelligent power management, and alternative and renewable power generation, in order to reduce the operational, economic and environmental vulnerabilities associated with the use and transportation of fossil fuels" (Nolan, April 2008).

The following list of facts further emphasis the need of the United States and thus the need for DoD to curtail its use of petroleum products:

- The U.S. consumes more than 20 million barrels of oil per day (Energy Information Administration, September 2008)
- A $10/barrel increase in oil costs DoD roughly $1.8B/year (DiPetto, November 2006)
- In 2007, Defense Energy Support Center purchased 136,060,000 barrels of petroleum products totaling nearly $11.5B (Defense Energy Support Center, August 2008)
- The U.S. imports nearly 60% of the oil it uses (Energy Information Administration, September 2008)

Figure 1 illustrates the United States' growing dependence on imported fossil fuels.

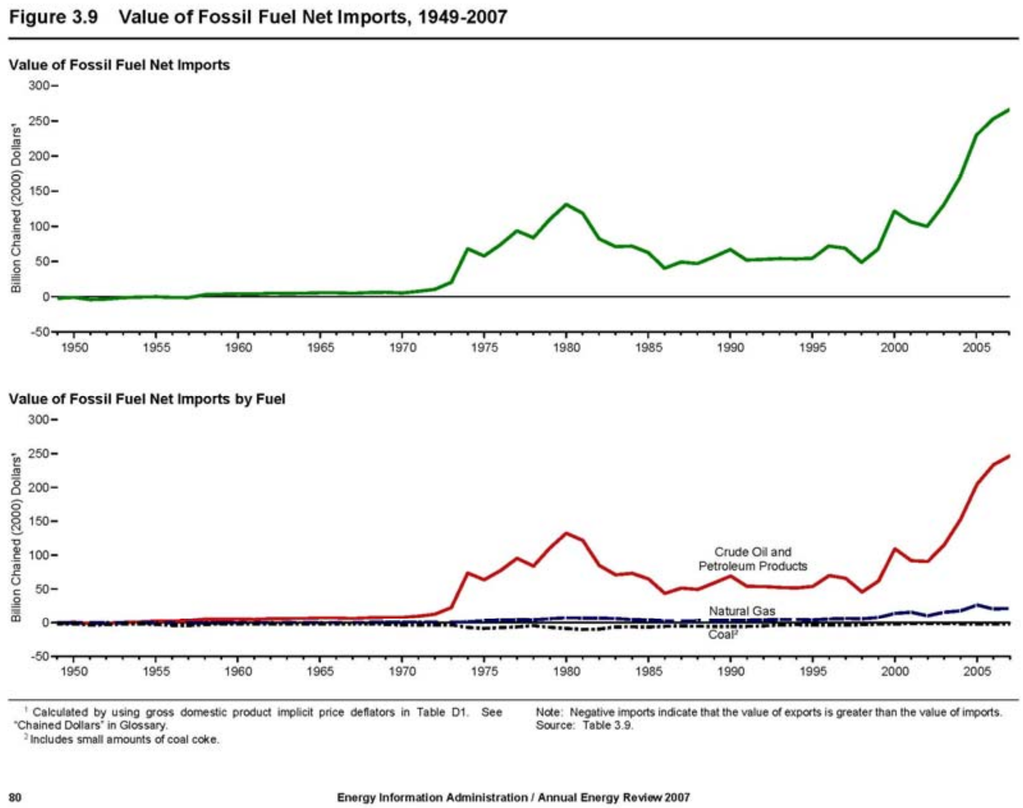

Figure 1. The graph shows the Value of Net Fuel Imports from 1949-2007 as well as the Value of Fossil Fuel Net Imports by Fuel during the same period, illustrating the United States' growing dependence on foreign oil (From Energy Information Administration, Annual Energy Review 2007).

Therefore, the accomplishment of PSTF's mission ensures the sustainment of some of the Nation's critical objectives at all three levels, i.e., strategic, operational, and tactical. Strategically, the U.S. is able to reduce its dependence on foreign oil while allowing the Department of Defense to reap significant costs savings and providing greater financial flexibility. Operationally, combatant commanders (COCOM) realize decreased demands on their logistics operations centers creating increased operational maneuverability, mobility, and flexibility. Additionally, the COCOM sees a curtailment of his troops' "footprints" thereby minimizing cultural intrusions and

increasing host nation confidence. Tactically, local units lessen their signature reducing the need for traditional fuel transport. As a result, risks to convoy personnel are diminished (Nolan, May 2007).

B. PURPOSE

To achieve effectively and efficiently its overall goals, NZ+ JCTD looks into three main categories: energy supply, energy demand, and smart energy distribution (Ong, December 2007). Energy supply entails the use of renewable and alternative power generation which reduces fuel consumption by generating power through a combination of renewable, traditional, and alternative power generation methods. Energy demand emphasizes the construction of enduring energy efficient structures (E3S) and implementation of enduring energy efficient technologies (E3T). E3S and E3T reduce consumption through efficient insulation, minimized air infiltration, low power consuming devices and intelligent power management. Serving as a conduit between energy supply and energy demand is the smart power distribution system. This system links intelligent devices that can communicate with an automated power manager. This power manager precisely matches supply with demand in any weather conditions to minimize excessive production and/or unnecessary energy loss (Nolan, May 2007).

The purpose of this study is to support one of the many NZ+ project initiatives. Specifically, this thesis assists in determining whether or not it is economically advantageous to install a geothermal HVAC system in a highly-insulated monolithic dome.

C. RESEARCH QUESTIONS

Many factors impact the design a geothermal HVAC system, including soil type, loop configuration, system capacity, trench expanse for horizontal closed loops, and bore hole depth for vertical closed loop (ToolBase Services, Geothermal Heat Pumps). These variables in turn determine costs associated with the system, both capital investment and operating and maintenance (O&M). The objective of this study is to determine whether

or not the geothermal heat pump in conjunction with an extremely well-insulated, monolithic dome, with respect to its size, is indeed a good financial decision.

(An open loop system relies on the presence of an adequate supply of suitable water, such as a pond or lake. For the purpose of this study, we will only examine closed looped systems, specifically the slinky coil horizontal ground loop system.)

D. METHODOLOGY

This analysis, and the report of the analysis, is based on an examination of the capital investment costs and O&M costs of the proposed system over the life cycle of the system. To accomplish this review, a business case analysis (BCA) was constructed. The BCA develops and compares the net present value of net cash flows associated with a structure equipped with a geothermal heat pump.

II. GEOTHERMAL OVERVIEW

A. THE GEOTHERMAL HEAT PUMP

Instead of producing heat like the typical conventional furnace that heats a home, a geothermal heat pump moves heat from one place to the other; it moves heat from a structure to the ground or from the ground to the structure (vice versa). The following description and diagram, Figure 2 illustrates the summer cooling process:

- The cool, liquid refrigerant enters the indoor coil during cooling. As it enters the coil, the temperature of the refrigerant is between 40 and 50 degrees.

- As warm, moist room air passes over the cool coil, the refrigerant inside absorbs the heat.

- The new cooler, drier air is circulated back into the room with a blower fan.

- The refrigerant moves into the compressor, which is a pump that raises the pressure so it will move through the system. The increased pressure from the compressor causes the refrigerant to heat to roughly 120 to 140 degrees.

- The hot vapor now moves into contact with the condenser (the underground loops), where the refrigerant gives up its heat to the cooler ground loop, then condenses back into a liquid.

- As the refrigerant leaves the compressor, it's still under high pressure. It reaches the expansion valve, where the pressure is reduced.

- The cycle is complete as the cool, liquid refrigerant re-enters the evaporator to pick up room heat (Geothermal, How It Works).

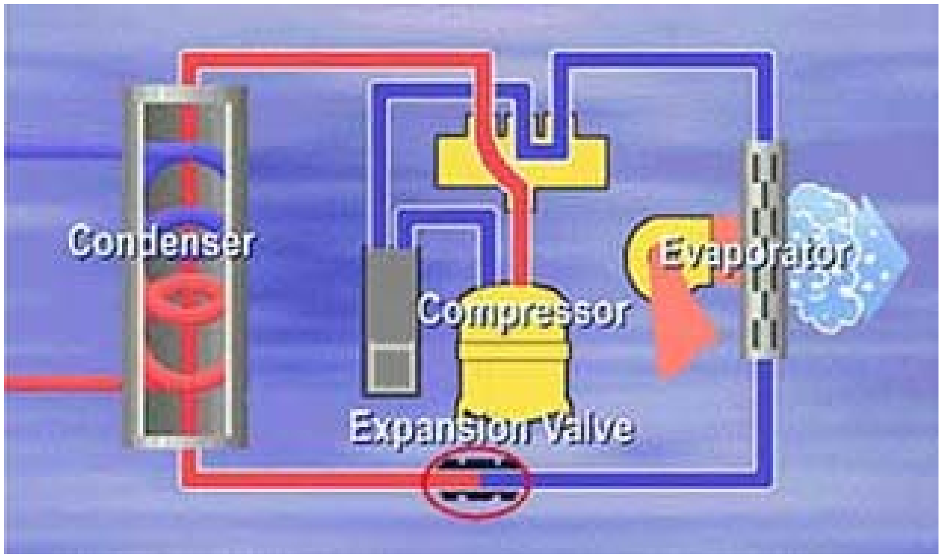

Figure 2. Illustrates the summer cooling process of a typical heat pump (From Geothermal, How It Works).

"During the winter, the reversing valve switches the indoor coil to function as the condenser, and the underground piping to act as the evaporator (GeoThermal, How It Works)."

B. WHAT IS GEOTHERMAL HEATING AND COOLING?

Geothermal heating and cooling relies on energy provided by the sun and stored in the earth. Absorbing approximately 46% of the sun's energy and acting as a "giant solar battery', the earth's ground temperature is relatively constant at a depth of about 15 feet with average temperature ranging between 42^0F and 77^0F (Weigand, 2008). This relatively constant temperature provides heating and cooling.

C. HOW GEOTHERMAL SYSTEMS WORK

Geothermal HVAC (heating, ventilation, and air conditioning) uses geothermal ground loops. These loops are made of high-strength, water or anti-freeze -filled polyethylene piping. During the summer (or warm months), the system cools the building by pulling heat from the building, carrying it through the system and placing it in the

ground, Figure 3. During the winter (or cold months), the system reverses itself and collects heat from the earth and carries it through the system and into the building or structure, Figure 4.

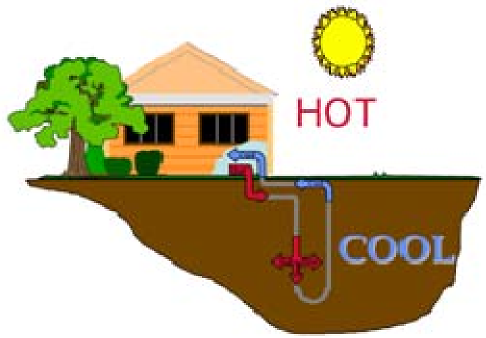

Figure 3. The flow of energy during the Summer or warmer months (From Weigand, 2008).

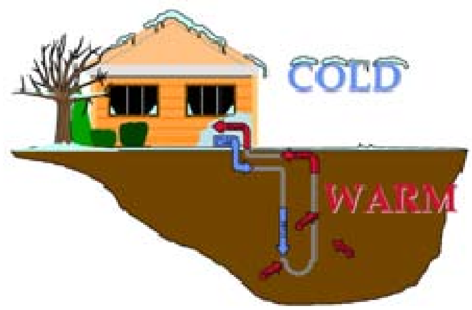

Figure 4. The flow of energy during the Winter or colder months (From Weigand, 2008).

D. CLOSED GROUND LOOP SYSTEMS

1. Horizontal Ground Loop

Commonly used for new construction because of the amount of trenching involved, horizontal ground loops are "typically one of the [most] economical choices (Geothermal, How It Works)," provided adequate soil or clay is available. In these systems, hundreds of feet of piping are placed in four to six feet deep trenches. A typical horizontal ground loop is 400 to 600 feet long for each ton of heating and cooling.

Figure 5. A simplified horizontal loop (From Geothermal, How It Works).

Though it is normally the most economical choice and advantageous in that the trenches are laid according to the lot size, horizontal loop systems are inappropriate for extreme climates as ground temperature fluctuates with the drastic temperature changes. Horizontal loops' susceptibility to ground temperature fluctuation is due to their relatively shallow burial depths. As shown in Figure 6, a burial depth of at least 30 feet is required to minimize ground temperature variations (Weigand, 2008).

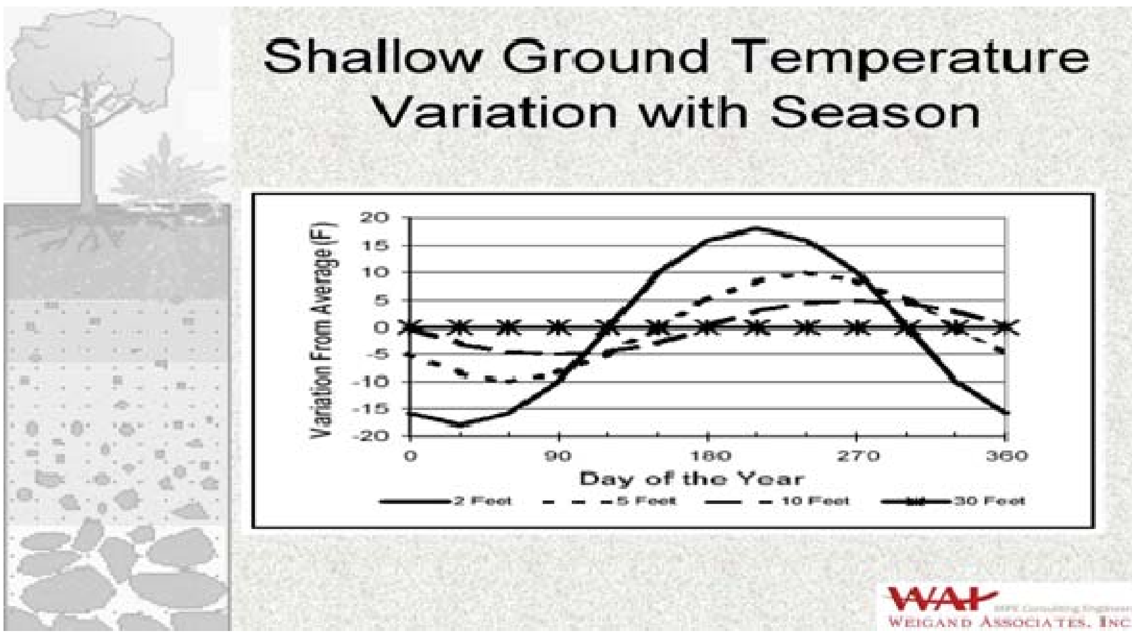

Figure 6. The graph displays ground temperature fluctuations according to the specific day of the year in relation to the depth below the surface (From Weigand, 2008).

2. Slinky Coil Ground Loop

Like the horizontal ground loop, the slinky coil loop, Figure 7, is installed in trenches approximately five feet in depth. However, these ground loops are more economic as they require far less space, i.e., smaller trenches. Since slinky coils use overlapped loops of piping rather than straight pipe, the trenching is typically one third to two thirds shorter than the traditional horizontal loop (GeoThermal, How It Works). Still, they too are inappropriate in more extreme climates.

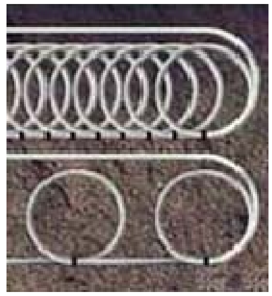

Figure 7. A sample slinky coil loop (From Weigand, 2008).

3. Vertical Ground Loop

Popular on smaller lots or in retrofits and more suited for extreme climates and rocky terrain, vertical ground loops offer a viable alternative to the horizontal and slinky coil ground loops. To install a vertical loop, a bore hole ranging from 150 to 450 feet deep is drilled. At these depths, undisturbed ground temperatures do not change. The typical vertical ground loop requires 300 to 600 feet of piping per ton of heating and cooling (Weigand, 2008). While less piping is required, this ground loop is typically more expensive than the horizontal ground systems because of the expense associated with drilling vertical holes vice excavating horizontal trenches.

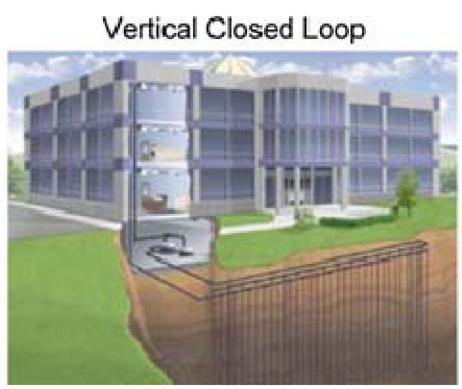

Figure 8. The typical vertical closed loop system (From Weigand, 2008).

E. CLOSED LOOP ADVANTAGES AND DISADVANTAGES SUMMARIZED (WEIGAND, 2008)

1. Vertical Loop

a. Advantages

- Smallest area requirement
- No impact due to surface temperature
- No ground water quality issues

b. Disadvantages

- Potential for field temperature rise over time
- Additional wells may be required over time
- High drilling costs

2. Horizontal Loop

a. Advantages

- Normally less expensive than drilling bore holes
- Does not require special equipment
- No ground water quality issues

B. Disadvantages

- Impacted by seasonal surface temperature changes
- Requires a large surface area

III. PROJECT BACKGROUND

A. RAPID EQUIPPING FORCE AND POWER SURETY TASK FORCE

The Army's Rapid Equipping Force (REF) began in 2002, but did not become a permanent organization until 2005. "The force's mission… is to identify immediate unmet needs of combat soldiers and satisfy those requirements within 90 to 180 days" (National Defense Magazine, October 2006), a process that can easily take years. Working with deployed units, REF works to meet unexpected, battlefield requirements.

To expedite the purchasing process, REF deploys 30 of its members in "forward teams" stationed throughout Iraq, Afghanistan, and logistics bases in Kuwait. The forward deployed teams buy small quantities of the required equipment and test it at in-theater field laboratories. Once gear has been issued to a unit, the forward teams assess usefulness/effectiveness of equipment by interviewing the end user, the troops (National Defense Magazine, October 2006).

As with requirement expediting, the REF has also been addressing the problem of improving power sources for forward-deployed forces. With commercial industry inputs, the force seeks to employ renewable energy options. Leading the REF effort to find "green solutions" is the Power Surety Task Force (PSTF). The PSTF, transitioning to OSD Energy Security Task Force in February 2008, constantly looks for new ideas and technologies. A recent success of the PSTF is the insulation of two inches of foam on fixed tents, Figures 9 and 10, decreasing fuel requirements and increasing troop morale and welfare – the troops live in these tents. Seeking its next success, the PSTF is exploring feasibility of installing geothermal heating and cooling on monolithic domes and other structures at forward operating bases (FOB).

	
Figure 9. Non-foamed tent (From Nolan, October 2008).	Figure 10. Tent once foam has been applied (From Nolan, October 2008).

B. NET ZERO PLUS JOINT CAPABILITY TECHNOLOGY DEMONSTRATION

As previously stated, the Net Zero Plus Joint Capability Technology Demonstration (NZ+ JCTD) initiative directly supports the mission of coordinating Department of the Defense efforts to operationalize efficient devices, practice conservation, intelligently manage power, and offer alternative and renewable power generation, in order to reduce the operational, economic and environmental vulnerabilities associated with the use and transportation of fossil fuels.

> By reducing demand, providing efficient distribution, and utilizing alternative energy sources, the FOB will minimize fuel consumption and ultimately reduce the risk to our service members. The emphasis will be on replacing temporary living, office, and operational facilities with energy efficient structures and integrating renewable energy technologies with improved energy generation to power those structures. An intelligent power distribution system that measures, analyzes, and connects power flow will effectively and efficiently manage source and demand management. The combined capabilities will establish an energy efficient FOB blueprint that may be utilized by tactical elements, operational commanders, theater planners, interagency organizations, and coalition partners. NZ+ JCTD will demonstrate reduced fuel demand, improved infrastructure and alternative energy supply seamlessly provided to the warfighter. This will save lives by reducing the need for traditional fuel transport. (NetZero Plus – Joint Capability Technology Demonstration, March 2008)

C. THE MONOLITHIC DOME

1. System Description

The monolithic dome was constructed at COB King located at the National Training Center (NTC) on Fort Irwin, CA. This Net Zero Structure minimizes air infiltration, thus reducing power requirements for heating and cooling, i.e., geothermal HVAC. A structural description as provided by the Power Surety Task Force follows.

- Steel reinforced concrete
- 54’-0” in diameter X 20’-0” high
- 2,300 ft^2 of total square footage
- 3,800 ft^2 of total surface area
- 7-inch wall thickness, three inches insulating foam and four inches of gunite, a dry mixture of cement and aggregate that is combined with water

2. Status

The monolithic dome at NTC was provided with off grid power capability. To satisfy the operational, lighting, and heating and cooling power requirements, the dome was outfitted with a tactical hybrid power generation (THPG) set that supplies 6Kw of “green” power. The THPG set included small sized wind turbines and photovoltaic panels which generate power from wind and solar as well as battery storage cells. Because this renewable power can be combined with generator power, it serves to enhance mission capability while providing constant, reliable power. Figure 11 shows the monolithic dome with its installed wind and solar alternative power sources.

Figure 11. Monolithic dome installed at National Training Center (NTC), Fort Irwin, CA with installed “green” power (From Nolan, October 2008).

THIS PAGE INTENTIONALLY LEFT BLANK

IV. THE BUSINESS CASE ANALYSIS

A. THE BUSINESS CASE ANALYSIS, DEFINED

The description and process diagram of the business case analysis (BCA) provided below was taken directly from the Defense Acquisition University website on July 24, 2008 located at https://acc.dau.mil/CommunityBrowser.aspx?id=32524.

A BCA is an expanded cost/benefit analysis. It assesses alternatives and weighs total cost against total benefits in an attempt to arrive at the optimum solution. The BCA identifies which alternative support options provide optimum mission performance given cost and other constraints. Developing the BCA should determine the following.

- The relative cost vs. benefits
- The methods and rationale used to quantify benefits and costs
- The impact and value of tradeoffs to include cost and sustainment
- Data required to support and to justify the strategy
- Sensitivity of the data to change
- Analysis and classification of risks
- A conclusion and recommendations

As a minimum, a BCA should include the following.

- An introduction that defines the case and its purpose
- The methods and assumptions that state the analysis methods
- Risk assessment that shows how results depend on important assumptions ('what if')
- Conclusions and recommendations for specific objectives and the results of the analysis

The BCA becomes an iterative process, conducted and updated as needed throughout the life cycle as program plans evolve and react to changes. Figure 12 illustrates the business case analysis.

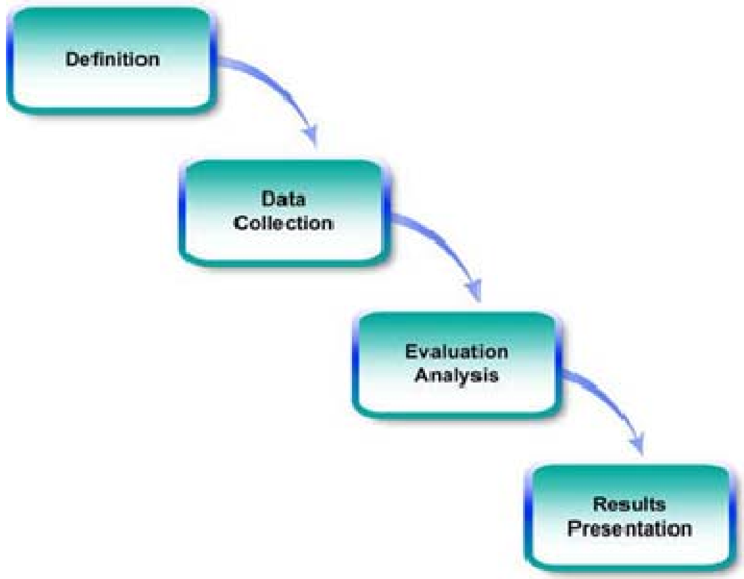

Figure 12. Business case analysis (BCA) as defined by the Defense Acquisition University (DAU).

B. THE BCA DEFINED

1. Definition

Definition sets the scope of the analysis. During the definition stage, analysts formulate the assumptions and constraints that guide the analysis. Analysts also identify the number of alternatives the BCA will consider.

2. Data Collection

Analysts identify the types of data needed, and classify it into categories. The analysts then identify potential data sources, and create a methodology for pursuing and obtaining the data. Analysts must identify all relevant data, to include performance data. The analysts also need to develop models to organize the data.

3. Evaluation Analysis

Analysts begin the "number crunching". Using the data collected, analysts build a case for each alternative, using both quantitative and qualitative data. Each alternative is compared against each other.

4. Results Presentation

Conclusions should state the case completely supporting the evidence from the preceding steps. Surprising or unexpected results or findings that could be misinterpreted should be pointed out. The written BCA should include a full description of the process the analysts used to arrive at its results. Quantitative data should usually be presented in the form of charts and graphs, accompanied by a narrative explaining the results. Finally, recommend a course of action to the decision-makers. A recommendation should be one that a reasonable person would find compelling.

C. THE BUSINESS CASE ANALYSIS, RUNNING THE NUMBERS

In this business case analysis, the life-cycle costs, specifically, investment and operations and maintenance, are examined.

1. Investment Costs

"Investment cost consists of the estimated cost of the investment phase, [which typically includes] the total cost of procuring the prime equipment, related support equipment, training, initial and war reserve spares, pre-planned product improvements and military construction" (Ong, December 2007). For this business case, we focused on the unit procurement costs and the installation costs.

2. Operations and Support Cost

"The O&S cost consists of the estimated cost of operating and supporting the fielded system, including all direct and indirect costs incurred in using the system, e.g., personnel, maintenance, and sustaining investment (replenishment spares). O&S cost is

the recurring cost incurred to maintain the operational readiness of the system throughout the life cycle of the system" (Ong, December 2007). For this business case, we will focus on the estimated recurring maintenance costs, the generator lease cost, and the estimated annual fuel costs.

3. Data

All baseline costs are provided in FY08$K. The source of all data was the Power Surety Task Force (J. Barniak, personal communication, September 22, 2008).

a. 3-ton HVAC System Costs

- Unit Procurement Cost - **$4.0**
- Installation Cost - **$2.0**
- Estimated Recurring Maintenance Costs – **$1.6**

Since the estimated recurring annual maintenance costs are $500 to $750 every four to six months, an average of the maximum ($2,250) and minimum ($1,000) recurring annual maintenance costs was used to calculate the overall estimated recurring annual maintenance costs.

b. 3-ton Geothermal System Costs

- Unit Procurement Cost - **$34.0**
- Installation Cost - **$25.0**
- Estimated Recurring Maintenance Costs – **$2.6**

Since the estimated recurring annual maintenance costs are $750 to $1,250 every four to six months, an average of the maximum ($3,750) and minimum ($1,500) recurring annual maintenance costs was used to calculate the overall estimated recurring annual maintenance costs.

c. 25kW Diesel Generator Set Annual Operation Costs

- Lease Cost - $2.8 per rotation

  Assume 12 rotations per year (10 rotations plus 2 internal training events). Therefore, the total yearly lease cost is as follows: $2,800 * 12 = **$33.6 per year**

- Estimated Annual Fuel Costs

  $16.1 – $37.1, depending on generator operational tempo

Assume: (1) Generator runs 24 hour per day

(2) 14 days per rotation, training rotation length

(3) Fuel: $4.00 per gallon

(4) Specific fuel usage estimated as follows:

At 25% load:

The estimated Fuel Usage = 1.0 gal per hour

Therefore, the fuel usage is estimated at 336 gal per rotation.

Thus, the yearly fuel costs are **$16,128 annually.**

(336 gal per rotation * $4.00 per gal * 12 rotations)

At 50% load:

The estimated Fuel Usage = 1.4 gal per hour

The estimated yearly fuel costs are **$22,579 annually**.

At 75% load:

The estimated Fuel Usage = 1.9 gal per hour

The estimated yearly fuel costs are **$30,643 annually**.

At Full load:

The estimated Fuel Usage = 2.3 gal per hour

The estimated yearly fuel costs are **$37,094 annually.**

4. Comparison of Traditional HVAC to Geothermal HVAC

To achieve effectively and efficiently its overall goals, NZ+ JCTD looks into three main categories: energy supply, energy demand, and smart energy distribution. For clarity we have developed the metric, *lambda*, which measures the percent savings in fuel normally used by the generator by installing the geothermal HVAC system as opposed to the traditional HVAC system. To examine the feasibility of a traditional 3-ton HVAC system versus that of a 3-ton geothermal HVAC system over a prescribed life cycle, the following procedure was implemented.

- The desired life cycle was determined, i.e., 10-year, 20-year, or 30-year
- The discount rate was set. For this thesis, the range 0% to 20% was used
- *Lambda* represents the fraction of fuel savings, or operating costs reduction, that must realized to get a positive NPV. *Lambda* was adjusted until a positive NPV was calculated.
- Once a positive NPV was realized, the specific discount rate and the appropriate *lambda* were noted and subsequently plotted as shown in Figure 13

For example, for a 10-year life cycle cost at a 4.0% discount rate *lambda* was found to be 29.5%. In other words, the geothermal HVAC system over a 10-year life cycle at a 4.0% discount rate needs to save 29.5% in fuel costs when compared to the traditional HVAC to realize a positive net present value.

The financial feasibility of the geothermal system was evaluated on the basis of net present value (NPV).

The **Net Present Value (NPV)** of an investment is defined as the sum of the present values of the annual cash flows. The annual cash flows are the Net Benefits (revenues minus costs) generated from the investment during its lifetime. These cash flows are discounted or adjusted by incorporating the uncertainty and time value of money. NPV is calculated as follows (Defense Procurement, July 2005).

$$NPV = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t}$$

where

t – the time of the cash flow

n – the total time of the project

r – the discount rate

C_t – the net cash flow at time

Discount rate is the rate used to discount future cash flows to their present values. An approach to choosing the discount rate factor is to decide the rate which the capital needed for the project could return if invested in an alternative venture. Discount rates ranging from 0% to 20% were examined.

For the purpose of this report, we are interested in that discount factor, based on reduced operating costs savings, at which the NPV of the installed geothermal HVAC system becomes positive. 10-year, 20-year, and 30-year life cycles were examined.

As noted in Figure 13, for example, at a 10% discount rate for 10-year, 20-year, and 30-year life cycles, it is required that the geothermal HVAC system save 54.9%, 41.3%, and 37.9%, respectively, in fuel costs at a 25% generator load when compared to the traditional HVAC system in order to achieve a positive NPV. Naturally, higher lambda values provide positive NPVs, but require more time.

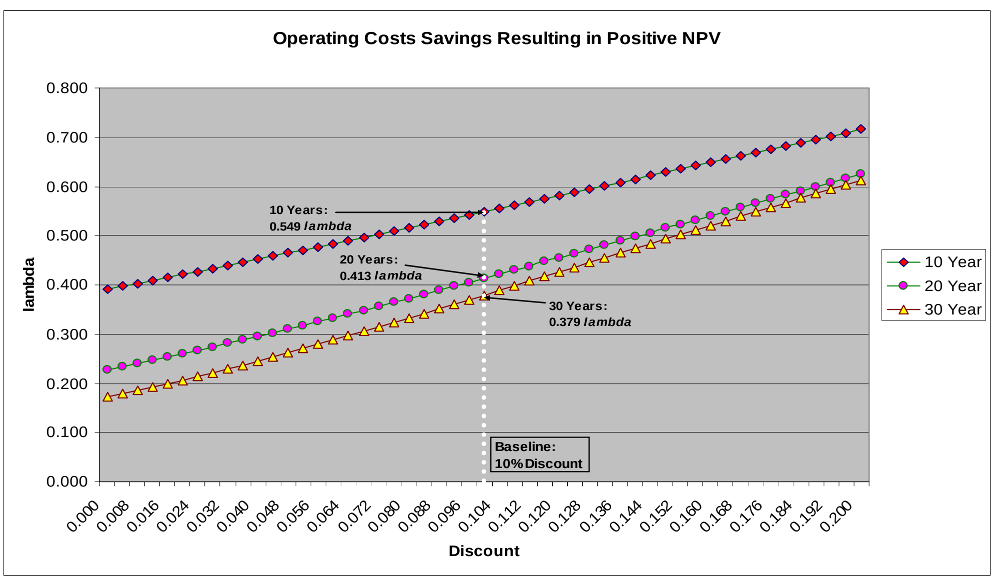

Figure 13. Amount of fuel savings, *lambda*, required to realize a positive NPV at a given discount rate at 25%-generator load.

Discount rates of 3.7%, 4.3% and 4.2% are of special note as they represent the current return of 10-year, 20-year, and 30-year U.S. Treasury notes, respectively (United States Treasury). Table 1 summarizes the U.S. Treasury note discount rates and the fuel savings required to achieve a positive NPV while Appendix A provides a compendium of values for *lambda* at discount rates ranging from 0% to 20% at a 25% generator load for which a positive NPV was realized.

LIFE CYCLE	**U.S. TREASURY NOTE DISCOUNT RATE**	**LAMBDA**
10-YEAR	3.7%	44.7%
20-YEAR	4.3%	30.1%
30-YEAR	4.2%	24.9%

Table 1. Amount of fuel savings, *lambda*, required to realize a positive NPV at the current 10-year, 20-year, and 30-year U.S. Treasury Note discount rates.

For example, over a 10-year cost life cycle at a 3.7% discount rate, the geothermal HVAC system needs to save 44.7% in fuel costs to realize a positive net present value. Likewise, over a 20-year cost life cycle at a 4.3% discount rate and a 30-year cost life cycle at a 4.2% discount rate, the geothermal HVAC system needs to save 30.1% and 24.9% in fuel costs, respectively.

D. SENSITIVITIES

As with Figure 13, Figure 14 displays the smallest lambda at which a positive NPV was realized. Figure 14, however, illustrates variations in total capital costs, i.e., unit procurement and installation costs. The baseline capital cost of $59,000, the actual cost for the 3-ton geothermal HVAC system currently installed in the monolithic dome at NTC, at a 3.7% discount rate, the 10-year U.S. Treasury note rate, was chosen.

To examine the problem from this aspect, the following steps were taken:

- The 10-year life cycle with a 3.7% discount rate was chosen as it coincides with the current 10-year U.S. Treasury note return rate.
- The capital cost was set. For this thesis, the range $6,000 (capital cost of traditional 3-ton HVAC system) to $75,000 (approximately 25% over the baseline capital cost of $59,000) was used.
- *Lambda* represents the fraction of fuel savings, or operating costs reduction, that must be realized to get a positive NPV. *Lambda* was adjusted until a positive NPV was calculated.
- Once a positive NPV was realized, the specific capital costs and the appropriate *lambda* were noted and subsequently plotted as shown in Figure 14.

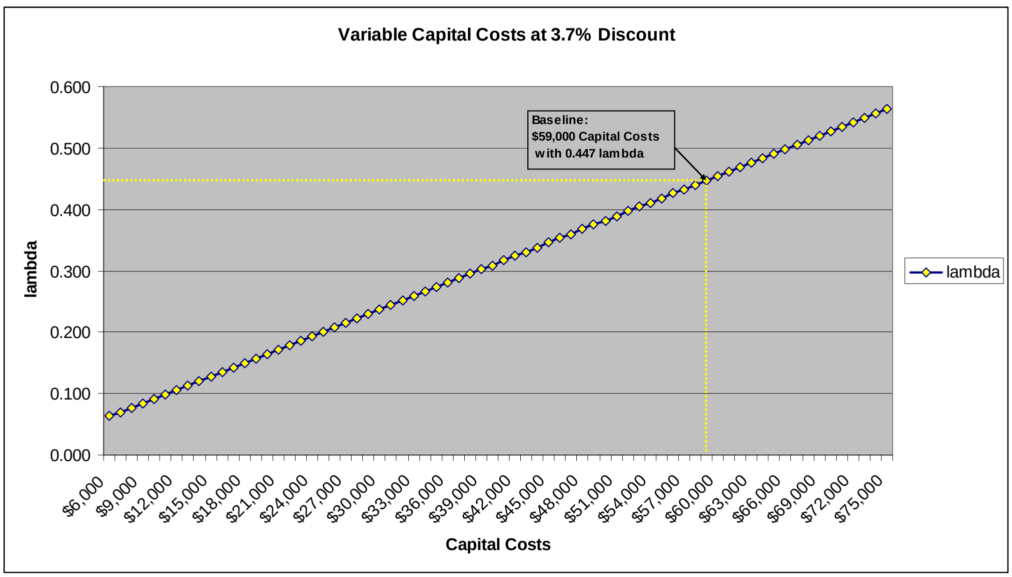

Figure 14. Amount of fuel savings, *lambda*, required to realize a positive NPV at a 25%-generator load at the specified capital costs over a 10-year life cycle.

Sensitivity analysis showed, as expected, that a smaller *lambda* would be required to achieve a positive NPV if the capital costs, unit procurement and installation costs, were reduced. Appendix B summarizes the *lambda* values for a 10-year life cycle at a discount rate of 3.7% and a 25% generator load for capital costs ranging from $6,000 to $75,000 for which a positive NPV was realized. In addition to varying the capital cost, the generator loads were also varied while holding the discount rate at 3.7% over a 10-

year cost life cycle. Figure 15 illustrates the 10-year cost life cycle while varying generator loads at 25%-, 50%-, 75%-, and full generator loads at a 3.7% discount rate.

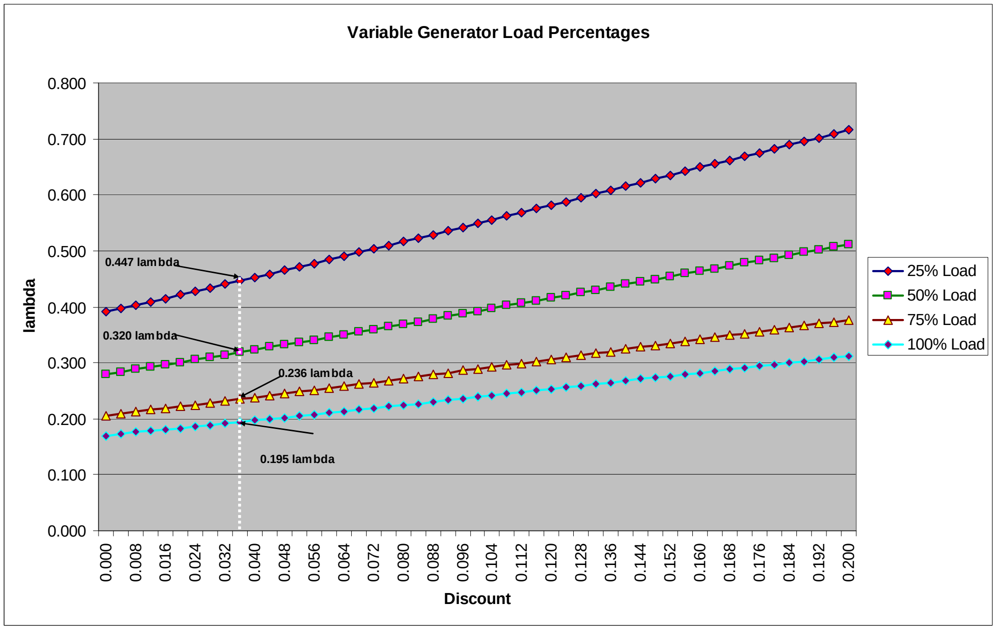

Figure 15. The baseline is drawn at 3.7% discount rate to coincide with the 10-year life cycle with generator loads of 25%, 50%, 75%, and 100%.

From Figure 15, it should be evident the higher the generator load the less lambda has to be in order to realize a positive NPV. The results of this analysis are shown in Table 2. The summary table of *lambda* values at various discount rates for the 10-year cost life cycle at generator loads of 25%, 50%, 75%, and 100% at $59,000 in capital costs for which a positive NPV was realized is provided in Appendix C.

GENERATOR LOAD	LAMBDA
25%	44.7%
50%	32.0%
75%	23.8%
100%	19.6%

Table 2. Amount of fuel savings, *lambda*, required to realize a positive NPV over a 10-year cost life cycle at a 10% discount rate with varying generator loads.

THIS PAGE INTENTIONALLY LEFT BLANK

V. CONCLUSIONS AND RECOMMENDATIONS

To achieve its overall goals, NZ+ JCTD looks into three main categories: energy supply, energy demand, and smart energy distribution. This business case analysis was performed on the 3-ton geothermal HVAC system installed in the extremely well-insulated monolithic dome at COB King located at the National Training Center on Fort Irwin, CA to evaluate its NPV over a 10-year, 20-year, and 30-year cost life cycle at a discount rate of 10%. The results of the baseline analysis are summarized in Table 3.

LIFE CYCLE	LAMBDA
10-YEAR	54.9%
20-YEAR	41.3%
30-YEAR	37.9%

Table 3. Amount of fuel savings, *lambda*, required to realize a positive NPV over a 10-year, 20-year, and 30-year cost life cycle at a 10% discount rate.

The metric, *lambda*, indicates whether the geothermal HVAC system is a financially attractive investment. Again, the measure in percent savings of fuel normally used by a generator to supply power to a geothermal HVAC system rather than a traditional HVAC system represents the value of *lambda*. For instance, we see that for a 30-year cost life cycle the geothermal HVAC system needs to save 37.9% of the fuel normally consumed by the traditional HVAC system to be financially attractive.

A. RECOMMENDATIONS FOR FURTHER RESEARCH

In order to perform a more thorough investigation into the economical feasibility of the geothermal HVAC system being installed in an extremely well-insulated monolithic dome the actual operational costs data should be obtained and used as the

basis of the analysis. In addition to re-evaluating the financial attractiveness of the geothermal HVAC system versus the traditional HVAC system, further studies should:

- determine whether or not the geothermal HVAC system in conjunction with a regular structure, with respect to its size, is a good financial decision;
- determine what areas of the world/climates are more conducive, in the sense of financial attraction, to the installation of a geothermal HVAC system.

APPENDIX A.

The following data set shows the amount of fuel savings, *lambda*, required to realize a positive NPV at a given discount rate at 25% generator load. For example, for a 20-year life cycle cost at a 4.0% discount rate *lambda* was found to be 29.5%. In other words, the geothermal HVAC system over a 20-year life cycle at a 4.0% discount rate needs to save 29.5% in fuel costs when compared to the traditional HVAC to realize a positive net present value.

10 Year			**20 Year**			**30 Year**	
Discount	***lambda***		**Discount**	***lambda***		**Discount**	***lambda***
0.000	0.391		0.000	0.227		0.000	0.172
0.004	0.397		0.004	0.233		0.004	0.179
0.008	0.403		0.008	0.240		0.008	0.185
0.012	0.409		0.012	0.246		0.012	0.192
0.016	0.415		0.016	0.253		0.016	0.199
0.020	0.421		0.020	0.260		0.020	0.206
0.024	0.427		0.024	0.266		0.024	0.214
0.028	0.433		0.028	0.273		0.028	0.221
0.032	0.440		0.032	0.281		0.032	0.229
0.036	0.446		0.036	0.288		0.036	0.237
0.040	0.452		0.040	0.295		0.040	0.245
0.044	0.458		0.044	0.302		0.044	0.253
0.048	0.465		0.048	0.310		0.048	0.262
0.052	0.471		0.052	0.317		0.052	0.270
0.056	0.477		0.056	0.325		0.056	0.279
0.060	0.484		0.060	0.333		0.060	0.288
0.064	0.490		0.064	0.341		0.064	0.297
0.068	0.497		0.068	0.348		0.068	0.306
0.072	0.503		0.072	0.356		0.072	0.315
0.076	0.509		0.076	0.364		0.076	0.324
0.080	0.516		0.080	0.372		0.080	0.333
0.084	0.522		0.084	0.381		0.084	0.342
0.088	0.529		0.088	0.389		0.088	0.351
0.092	0.536		0.092	0.397		0.092	0.361
0.096	0.542		0.096	0.405		0.096	0.370
0.100	0.549		0.100	0.413		0.100	0.379
0.104	0.555		0.104	0.422		0.104	0.389
0.108	0.562		0.108	0.430		0.108	0.398
0.112	0.569		0.112	0.438		0.112	0.408
0.116	0.575		0.116	0.447		0.116	0.417

10 Year			20 Year			30 Year	
Discount	***lambda***		**Discount**	***lambda***		**Discount**	***lambda***
0.120	0.582		0.120	0.455		0.120	0.427
0.124	0.588		0.124	0.464		0.124	0.436
0.128	0.595		0.128	0.472		0.128	0.446
0.132	0.602		0.132	0.481		0.132	0.455
0.136	0.608		0.136	0.489		0.136	0.465
0.140	0.615		0.140	0.498		0.140	0.474
0.144	0.622		0.144	0.506		0.144	0.484
0.148	0.629		0.148	0.515		0.148	0.493
0.152	0.635		0.152	0.523		0.152	0.502
0.156	0.642		0.156	0.532		0.156	0.512
0.160	0.649		0.160	0.540		0.160	0.521
0.164	0.655		0.164	0.549		0.164	0.530
0.168	0.662		0.168	0.557		0.168	0.540
0.172	0.669		0.172	0.566		0.172	0.549
0.176	0.675		0.176	0.574		0.176	0.558
0.180	0.682		0.180	0.583		0.180	0.567
0.184	0.689		0.184	0.591		0.184	0.576
0.188	0.696		0.188	0.600		0.188	0.586
0.192	0.702		0.192	0.608		0.192	0.595
0.196	0.709		0.196	0.616		0.196	0.604
0.200	0.716		0.200	0.625		0.200	0.613

APPENDIX B.

The following data set shows the amount of fuel savings, *lambda*, required to realize a positive NPV at a 25% generator load at the specified capital costs over a 10-year cost life cycle at a 3.7% discount rate. For example, at a capital cost of $50,000, under the conditions mentioned above, *lambda* was found to be 38.2%. In other words, the geothermal HVAC system over a 10-year life cycle at a 3.7% discount rate needs to save 38.2% in fuel costs when compared to the traditional HVAC to realize a positive net present value.

Capital Costs	***Lambda***
$6,000	0.063
$7,000	0.070
$8,000	0.077
$9,000	0.084
$10,000	0.092
$11,000	0.099
$12,000	0.106
$13,000	0.113
$14,000	0.121
$15,000	0.128
$16,000	0.135
$17,000	0.142
$18,000	0.150
$19,000	0.157
$20,000	0.164
$21,000	0.171
$22,000	0.179
$23,000	0.186
$24,000	0.193
$25,000	0.200
$26,000	0.208
$27,000	0.215
$28,000	0.222
$29,000	0.230
$30,000	0.237
$31,000	0.244
$32,000	0.251
$33,000	0.259
$34,000	0.266

Capital Costs	***Lambda***
$35,000	0.273
$36,000	0.280
$37,000	0.288
$38,000	0.295
$39,000	0.302
$40,000	0.309
$41,000	0.317
$42,000	0.324
$43,000	0.331
$44,000	0.338
$45,000	0.346
$46,000	0.353
$47,000	0.360
$48,000	0.368
$49,000	0.375
$50,000	0.382
$51,000	0.389
$52,000	0.397
$53,000	0.404
$54,000	0.411
$55,000	0.418
$56,000	0.426
$57,000	0.433
$58,000	0.440
$59,000	0.447
$60,000	0.455
$61,000	0.462
$62,000	0.469
$63,000	0.476

Capital Costs	***Lambda***
$64,000	0.484
$65,000	0.491
$66,000	0.498
$67,000	0.505
$68,000	0.513
$69,000	0.520
$70,000	0.527
$71,000	0.535
$72,000	0.542
$73,000	0.549
$74,000	0.556
$75,000	0.564

APPENDIX C.

The following data set shows the amount of fuel savings, *lambda*, required to realize a positive NPV at discount rates ranging from 0% to 20% to coincide with the 10-year cost life cycle and a capital cost of $59,000 with generator loads of 25%, 50%, 75%, and 100%. For instance, for a discount rate of 4.0% with a 50.0% generator load, *lambda* was found to be 32.3% in order to realize a positive net present value.

$16,128.00	at 25.0%	$22,579.20	at 50.0%	$30,643.20	at 75.0%	$37,094.40	at 100.0%
Discount	Lambda	Discount	lambda	Discount	Lambda	Discount	lambda
0.000	0.391	0.000	0.280	0.000	0.206	0.000	0.170
0.004	0.397	0.004	0.284	0.004	0.209	0.004	0.173
0.008	0.403	0.008	0.288	0.008	0.212	0.008	0.176
0.012	0.409	0.012	0.292	0.012	0.216	0.012	0.178
0.016	0.415	0.016	0.297	0.016	0.219	0.016	0.181
0.020	0.421	0.020	0.301	0.020	0.222	0.020	0.183
0.024	0.427	0.024	0.305	0.024	0.225	0.024	0.186
0.028	0.433	0.028	0.310	0.028	0.228	0.028	0.189
0.032	0.440	0.032	0.314	0.032	0.232	0.032	0.191
0.036	0.446	0.036	0.319	0.036	0.235	0.036	0.194
0.040	0.452	0.040	0.323	0.040	0.238	0.040	0.197
0.044	0.458	0.044	0.328	0.044	0.241	0.044	0.200
0.048	0.465	0.048	0.332	0.048	0.245	0.048	0.202
0.052	0.471	0.052	0.337	0.052	0.248	0.052	0.205
0.056	0.477	0.056	0.341	0.056	0.251	0.056	0.208
0.060	0.484	0.060	0.346	0.060	0.255	0.060	0.211
0.064	0.490	0.064	0.350	0.064	0.258	0.064	0.213
0.068	0.497	0.068	0.355	0.068	0.262	0.068	0.216
0.072	0.503	0.072	0.359	0.072	0.265	0.072	0.219
0.076	0.509	0.076	0.364	0.076	0.268	0.076	0.222
0.080	0.516	0.080	0.369	0.080	0.272	0.080	0.225
0.084	0.522	0.084	0.373	0.084	0.275	0.084	0.227
0.088	0.529	0.088	0.378	0.088	0.279	0.088	0.230
0.092	0.536	0.092	0.383	0.092	0.282	0.092	0.233
0.096	0.542	0.096	0.387	0.096	0.286	0.096	0.236
0.100	0.549	0.100	0.392	0.100	0.289	0.100	0.239
0.104	0.555	0.104	0.397	0.104	0.292	0.104	0.242
0.108	0.562	0.108	0.402	0.108	0.296	0.108	0.245
0.112	0.569	0.112	0.406	0.112	0.299	0.112	0.247

$16,128.00	at 25.0%	$22,579.20	at 50.0%	$30,643.20	at 75.0%	$37,094.40	at 100.0%
Discount	Lambda	Discount	lambda	Discount	Lambda	Discount	lambda
0.116	0.575	0.116	0.411	0.116	0.303	0.116	0.250
0.120	0.582	0.120	0.416	0.120	0.306	0.120	0.253
0.124	0.588	0.124	0.420	0.124	0.310	0.124	0.256
0.128	0.595	0.128	0.425	0.128	0.313	0.128	0.259
0.132	0.602	0.132	0.430	0.132	0.317	0.132	0.262
0.136	0.608	0.136	0.435	0.136	0.320	0.136	0.265
0.140	0.615	0.140	0.440	0.140	0.324	0.140	0.268
0.144	0.622	0.144	0.444	0.144	0.328	0.144	0.271
0.148	0.629	0.148	0.449	0.148	0.331	0.148	0.274
0.152	0.635	0.152	0.454	0.152	0.335	0.152	0.276
0.156	0.642	0.156	0.459	0.156	0.338	0.156	0.279
0.160	0.649	0.160	0.463	0.160	0.342	0.160	0.282
0.164	0.655	0.164	0.468	0.164	0.345	0.164	0.285
0.168	0.662	0.168	0.473	0.168	0.349	0.168	0.288
0.172	0.669	0.172	0.478	0.172	0.352	0.172	0.291
0.176	0.675	0.176	0.483	0.176	0.356	0.176	0.294
0.180	0.682	0.180	0.487	0.180	0.359	0.180	0.297
0.184	0.689	0.184	0.492	0.184	0.363	0.184	0.300
0.188	0.696	0.188	0.497	0.188	0.366	0.188	0.303
0.192	0.702	0.192	0.502	0.192	0.370	0.192	0.306
0.196	0.709	0.196	0.507	0.196	0.373	0.196	0.309
0.200	0.716	0.200	0.511	0.200	0.377	0.200	0.311

LIST OF REFERENCES

Defense Energy Support Center (DESC). FY2007 fact book. Retrieved August 4, 2008, from https://www.desc.dla.mil/DCM/Files/Factbook_2007_Final.pdf

Defense Procurement. (2005, July). Contract Pricing Reference Guide (Chapter 9). Retrieved August 8, 2008, from http://www.acq.osd.mil/dpap/cpf/contract_pricing_reference_guides.html

DiPetto, C. (2006, November 8). Energy efficiency for tactical systems. Retrieved December 6, 2008, from www.dau.mil/conferences/presentations/2006_PEO_SYSCOM/wed/B3-DiPetto.pdf

Energy Information Administration. Annual energy review 2007. Retrieved August 13, 2008 from http://www.eia.doe.gov/aer/

Energy Information Administration. Petroleum basic statistics. Updated September 2008. Retrieved December 5, 2008, from http://www.eia.doe.gov/basics/quickoil.html

GeoThermal. How it works: Anatomy of a heat pump. Retrieved August 5, 2008, from http://www.alliantenergygeothermal.com/stellent2/groups/public/documents/pub/geo_how_001210.hcsp

GeoThermal. How it works: Anatomy of a heat pump. Retrieved August 5, 2008, from http://www.alliantenergygeothermal.com/stellent2/groups/public/documents/pub/geo_how_001212.hcsp#P43_3582

National Defense Magazine. (2006, October). Army ‘Rapid Equipping Force’ taking root, chief says, Retrieved November 10, 2008, from http://www.nationaldefensemagazine.org/archive/2006/October/Pages/ArmysRapid2837.aspx

Net Zero Plus – Joint capability technology demonstration. (2008, March 31). *Implementation Directive*. Retrieved July 24, 2008, from Power Surety Tack Force.

Nolan, D. (2007, May). Power surety task force. *Power Surety for Enduring Operations*. Retrieved July 30, 2008, from http://www.usifi.com/pdf/Nolan_Outlook2007.ppt

Nolan, D. (2008, April). Power surety task force. *Energy Security for Enduring Operations*. Retrieved July 30, 2008, from http://usapc.army.mil/Dan%20Nolan%20DESC%20World%20Wide%20Apr%2008.ppt

Ong, H. M. D. (2007, December). Conducting a business case analysis for net zero plus – Joint Concept Technology Demonstration (JCTD) (Master's thesis, Naval Postgraduate School, Monterey, CA).

ToolBase Services. Geothermal heat pumps. Retrieved December 5, 2008, from http://www.toolbase.org/Technology-Inventory/HVAC/geothermal-heat-pumps

United States Treasury. Daily Treasury yield curve rates. Retrieved October 1, 2008, from http://www.ustreas.gov/offices/domestic-finance/debt-management/interest-rate/yield_historical_main.shtml

Weigand, M. A. Ground source earth coupling design principles. Retrieved July 24, 2008, from http://www.wainet.net/WAI%20-%20GEOTHERMAL%20CONFERENCE%202008.pdf

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Dr. Dan Nussbaum
   Naval Postgraduate School
   Monterey, California

4. Ms. Barbara Brygider
   Power Surety Task Force
   Washington, D.C.